(12) UK Patent Application (19) GB (11) 2 060 317 A

(21) Application No **8031090**
(22) Date of filing **26 Sep 1980**
(30) Priority data
(31) **2939252**
2940140
(32) **27 Sep 1979**
3 Oct 1979
(33) **Fed. Rep. of Germany (DE)**
(43) Application published
29 Apr 1981
(51) **INT CL³**
H04L 25/00
(52) Domestic classification
H4P X
(56) Documents cited
None
(58) Field of search
H4P
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(54) Push-pull data transmission

(57) The invention relates to a device for push-pull transmission of items of binary information, wherein in order to improve the ratio of the information which can be simultaneously transmitted to the number of lines in a line group comprising at least three lines, more than two different potentials are produced on the lines whilst maintaining a constant potential sum in the line groups. Two or more line groups can serve to form phantom circuits. As shown, push-pull transmitters such as GTS1, GTS2 and GTS3 are each connected to different pairs of *n* transmission lines such as L1, L2, L3. A coder SCN3 controls the transmitters so as to produce signal states on the lines corresponding to respective combinations of binary input signals E1, E2.

FIG 1

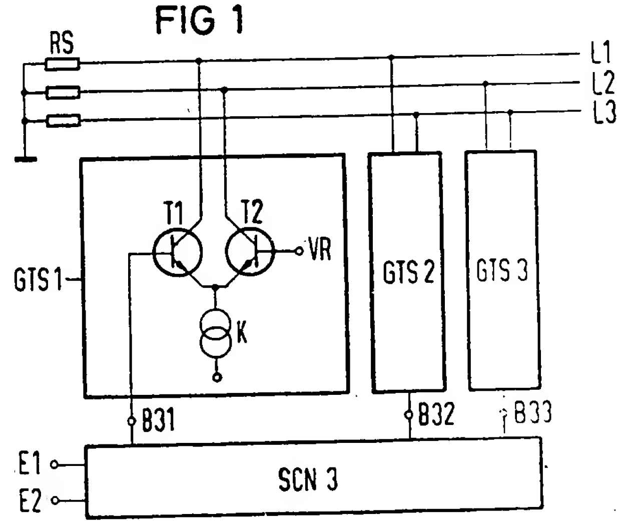

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FIG 1

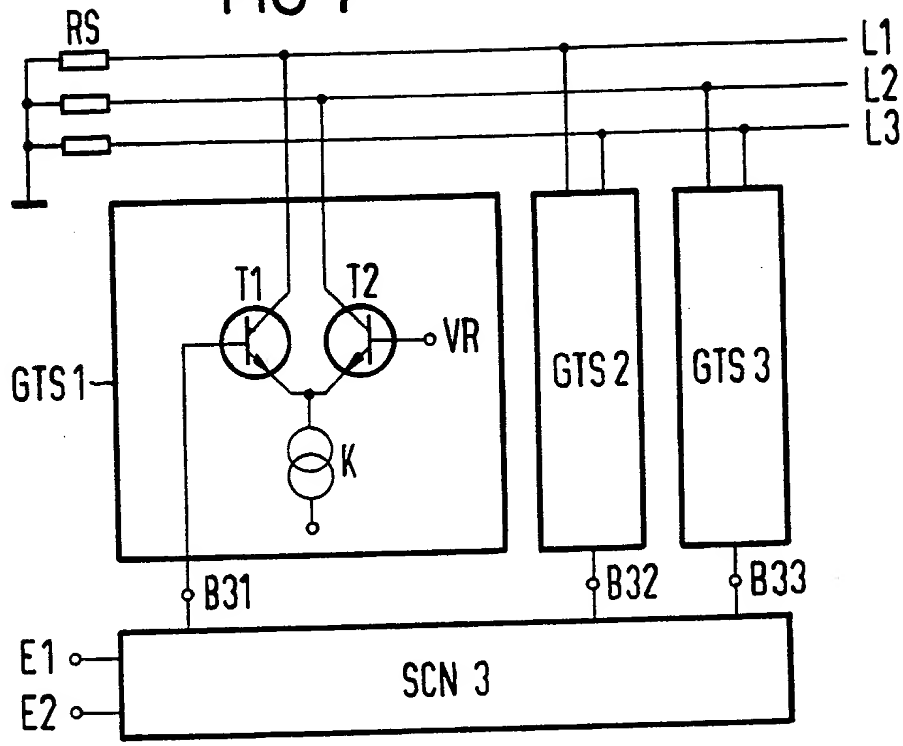

RS
L1
L2
L3
T1
T2
VR
GTS 1
GTS 2
GTS 3
K
B31
B32
B33
E1
E2
SCN 3

FIG 2

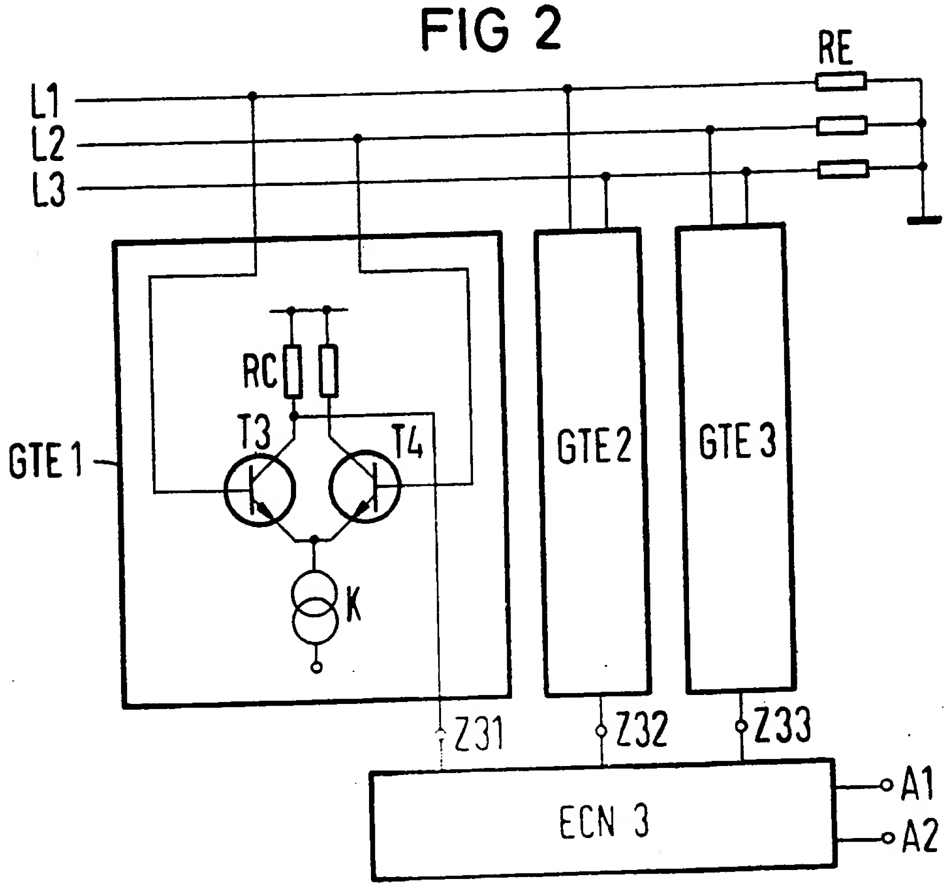

RE
L1
L2
L3
RC
T3
T4
GTE 1
GTE 2
GTE 3
K
Z31
Z32
Z33
ECN 3
A1
A2

FIG 3

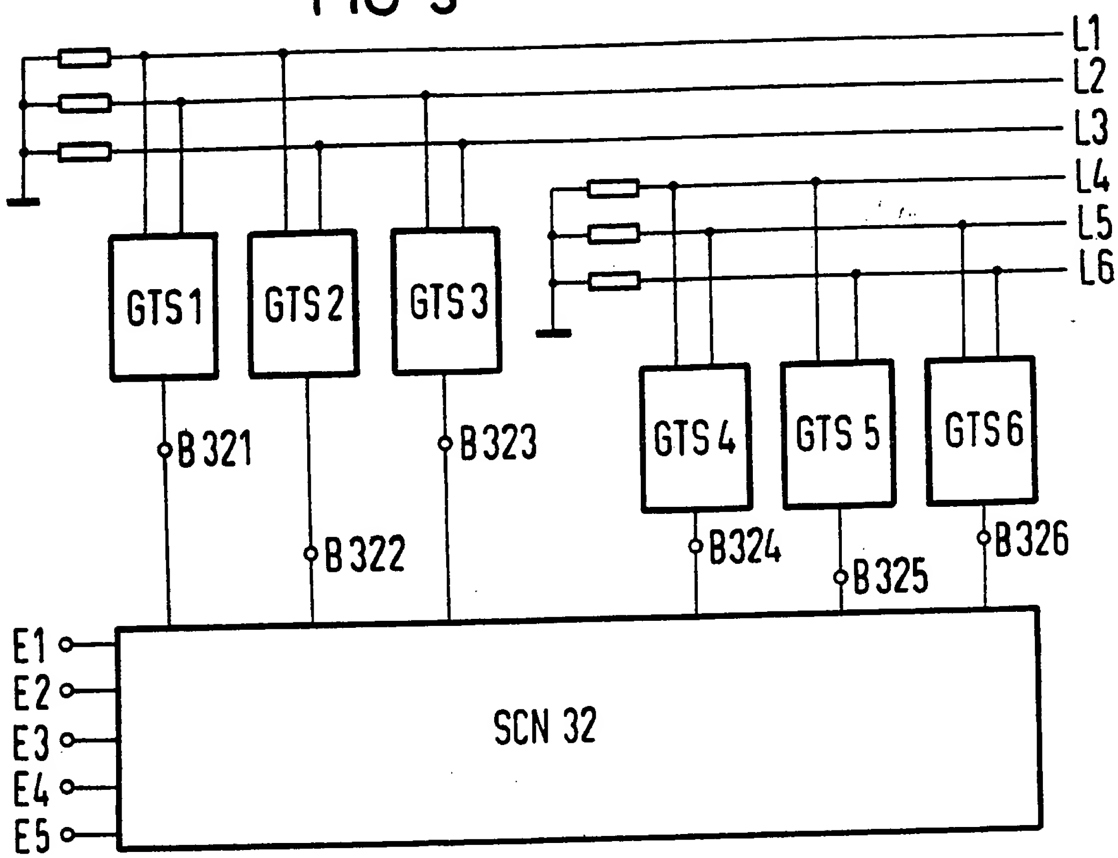

L1
L2
L3
L4
L5
L6
GTS1
GTS2
GTS3
GTS4
GTS5
GTS6
B321
B322
B323
B324
B325
B326
E1
E2
E3
E4
E5
SCN 32

FIG 4

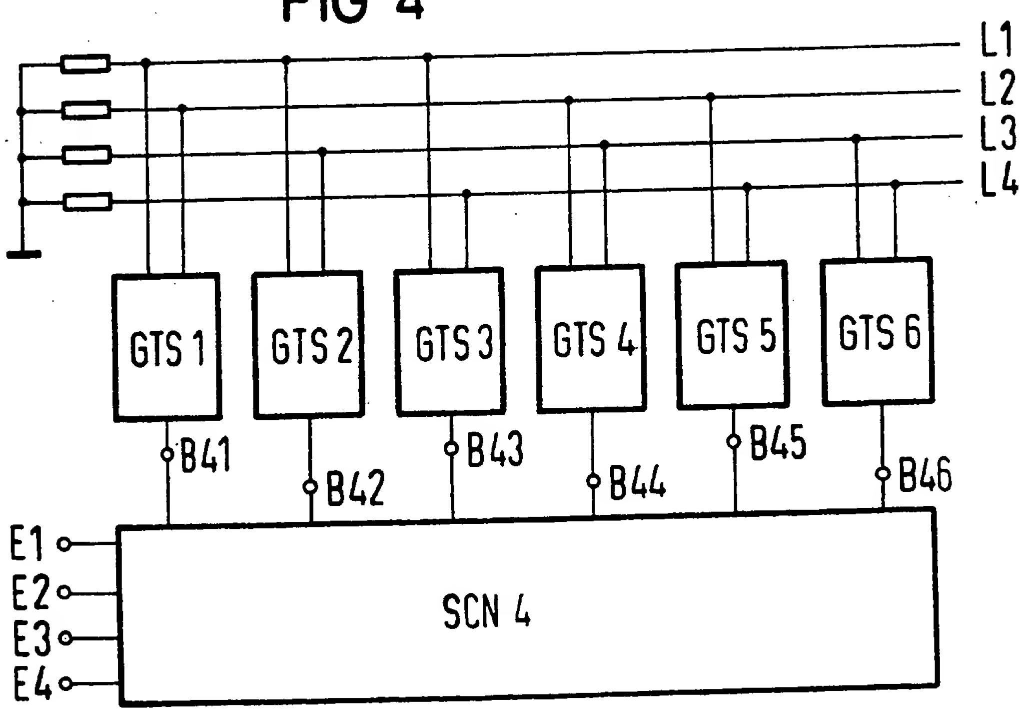
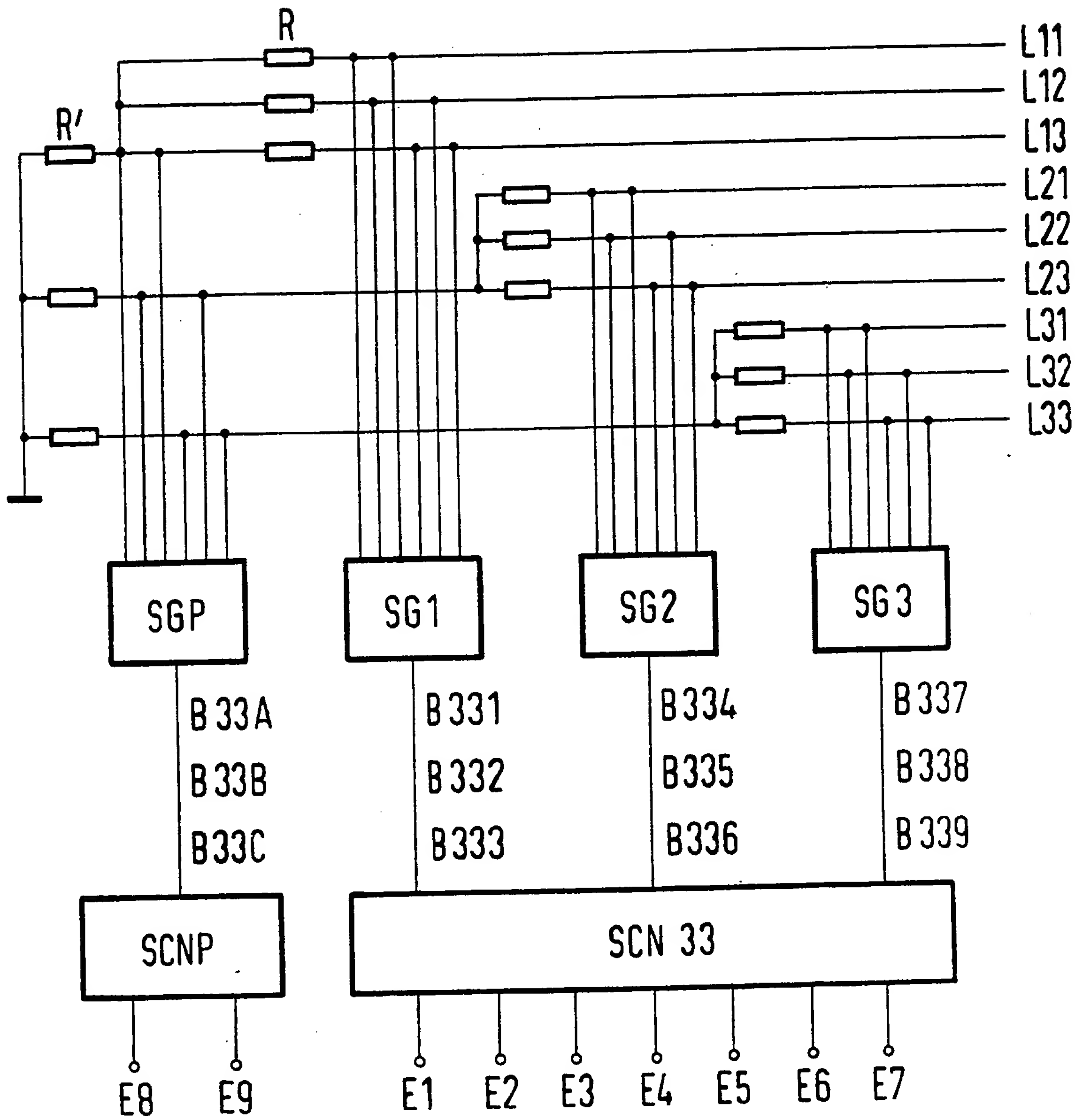

L1
L2
L3
L4
GTS 1
GTS 2
GTS 3
GTS 4
GTS 5
GTS 6
B41
B42
B43
B44
B45
B46
E1
E2
E3
E4
SCN 4

FIG 5


R
R'
L11
L12
L13
L21
L22
L23
L31
L32
L33
SGP
SG1
SG2
SG3
B33A
B33B
B33C
B331
B332
B333
B334
B335
B336
B337
B338
B339
SCNP
SCN 33
E8
E9
E1
E2
E3
E4
E5
E6
E7

SPECIFICATION

Push-pull data transmission

The invention relates to a data transmission system for push-pull transmission of binary information.

The push-pull principle is used with preference for transmitting data between two opposite stations in which equal earth potentials are not assured. The transmission of push-pull signals on a double line at least largely suppresses common mode interference since at the receiving end an analysis is only carried out of the potential difference between the two lines on the basis of the sign of which the information is formed.

The parallel transmission of a plurality of bits, for example between various units within a data processing system, over a corresponding number of double lines involves a considerable outlay in terms of lines and line plugs, the unpleasant manifestation of which is a large space requirement and high costs.

It is generally known to form a so-called phantom circuit from two double lines and thus to improve the ratio of the information which can be simultaneously transmitted to the overall number of physical lines — in the following referred to as transmission capacity — from 0.5 bits to 0.75 bits.

The aim of the invention is to provide means by which the transmission capacity can be further increased.

According to the present invention there is provided a data transmission system comprising *n* lines, where *n* is greater than or equal to three, connected to at least *n* push-pull transmitters, each transmitter being connected to a different pair of the lines, coder means responsive to binary input signals supplied thereto to control the transmitters so as to produce signal states on the lines corresponding to respective combinations of the input signals, and receiving means comprising a plurality of receivers each responsive to the states of a different pair of the lines and coder means arranged to produce binary output signal combinations corresponding to respective input signal combinations. Preferably $\frac{1}{2}n(n-1)$ transmitters are employed. The number of receivers will usually be the same as the number of transmitters although as will be seen below, it is sometimes possible to reduce the number of receivers.

With $\frac{1}{2}n(n-1)$ transmitters the maximum information capacity (where no phantom circuits are provided) is $\log_2(n!)$ and thus, for transmission in pure binary, preferably the transmitter coder means has *k* binary inputs where *k* is the largest integer less than $\log_2(n!)$.

In some circumstances it may be preferable to divide the lines into groups of at least three lines, each group being assigned a separate group of $\frac{1}{2}x(x-1)$ transmitters, where *x* is the number of lines in the relevant group. The groups may all have the same number of lines, in which case, for *m* groups, $x=n/m$.

The coder means for the transmitters of each group may operate independently, or some may be interdependent, with shared inputs, for a greater bit capacity (since, in general the largest integer less than the sum of the $\log_2(x!)$ will be greater than the sum of the largest integers less than $\log_2(x!)$.

The groups may be combined to form phantom circuits, and with three or more groups the phantom circuits may be operated in the same way as the line circuits: as with the coder means for the groups, the coder means for the transmitters of the phantom circuits may be independent of, or may share inputs with, those for the lines.

Some exemplary embodiments of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 illustrates the principle of a transmitting device for push-pull transmission of two bits across a three-wire line group;

Figure 2 illustrates the receiving device which corresponds to the transmitting device shown in figure 1;

Figure 3 illustrates a transmitting device for the transmission of 5 bits across two three-wire line groups;

Figure 4 illustrates a transmitting device for the transmission of 4 bits across a four-wire line group; and

Figure 5 illustrates a transmitting device for the transmission of 9 bits across three three-wire line groups exploiting phantom circuits.

If one considers push-pull transmission across a double line, it will become obvious that the line potentials must differ from one another in each logic state in order that they can be interrogated, without reference to earth potential, by means of a differential amplifier, and that the sum of the potentials is constant. If one of the potentials is arbitrarily designated zero, the values shown in Table 1 will apply.

TABLE 1

Signal	Potentials L1	Potentials L2	Potential Sum
0	0	1	1
1	1	0	1

The principle which forms the basis of push-pull transmission on a double line can be extended to a group of n lines where n is greater than two. In the case of a line group where n=3 lines the values shown in Table 2 will apply.

TABLE 2

Potentials L1	Potentials L2	Potentials L3	Potential Sum
0	1	2	3
0	2	1	3
1	2	0	3
1	0	2	3
2	0	1	3
2	1	0	3

Thus it is possible to transmit six different logic states and thus $\log_2 (6)$ bits where the symbol $\log_2$ signifies, in known manner, the logarithm to the base 2.

Table 3 illustrates a few important values in dependence upon the number n of lines in a line group.

TABLE 3

Lines	Potentials	Potential Sum	Information (bits)	Information/ per line (bits)
2	2	1	1	0.5
3	3	3	2.585	0.86
4	4	6	4.585	1.14
5	5	10	6.907	1.39
6	6	15	9.492	1.58
n	n	$(n-1)n/2$	$\log_2(n!)$	$[\log_2(n!)]/n$

Figure 1 illustrates a transmitting device for push-pull transmission of two bits over three lines L1 to L3. The resistors RS, whose value corresponds to the characteristic impedance of the lines, form the load resistances for the individual transmitters GTS1 to GTS3 which are designed as push-pull amplifiers. As in the exemplary embodiments to be discussed further in the description, the individual transmitters are of identical construction and each contain two transistors T1, T2 whose emitters are commonly connected to a constant current source K. The base of one transistor T1 is connected to an

intermediate (control) signal B31. The base of the other transistor T2 is connected to a fixed reference potential VR. The collectors of the two transistors T1 and T2 are connected to the lines L1 and L2 respectively.

The two other push-pull transmitters GTS2 and GTS3 are controlled in a similar manner by the transmitter-end intermediate signals B32 and B33. The collectors of the transistors of these individual transmitters are connected to the lines L1, L3 and L2, L3 respectively. This exhausts all possible combinations, and additional transpositions are not permitted. For example it would not be possible to increase the transmission power by connecting a fourth individual transmitter. On the other hand polarity reversals can be effected as these merely correspond to an inversion of the relevant intermediate signal.

The list of the possible potentials on the lines L1 to L3 which corresponds to the six possible states and which has already been given in Table 2 has been shown again in Table 4 in the form of voltage units. Here the logic values of the intermediate signals B31 to B33 have been given.

TABLE 4

E1	E2	B31	B32	B33	L1	L2	L3
1	1	1	1	1	2	1	0
1	0	1	1	0	2	0	1
		1	0	0	1	2	0
		0	1	1	1	0	2
0	1	0	0	1	0	2	1
0	0	0	0	0	0	1	2

The intermediate signals B31 to B33 are derived by a transmitting end coder network SCN3 (Figure 1) from the input signals E1 and E2 which are to be transmitted. However as the input signals E1 and E2 can only assume four different logic states, of the six different logic states arising from the possible potential distributions on the lines L1 to L3, any two thereof are superfluous. Preference will be given to those four potential distributions in respect of which recoding of the input signals E1 and E2 to the intermediate signals B31 to B33 can be effected most easily. An assignment of this kind can be seen from Table 4 if this is read row by row. This shows that in the event of push-pull transmission of 2 bits over a three-wire line group, under the conditions which have been selected the transmitting end coder network is so to speak degenerated as, since B31=E1, B32=E1, and B33=E2, it exerts only a branching functiuon or switch-through function.

Figure 2 illustrates the receiving device which is assigned to the transmitting device illustrated in Figure 1 and which comprises push-pull receivers GTE1 to GTE3 which are identical to one another. As illustrated in Figure 2 in the example of the push-pull receiver GTE1, each receiver contains two transistors T3 and T4 whose coupled emitters are connected to a constant current source K. The base electrodes of the transistors are connected to the lines L1 and L2 which are terminated by resistors RE correspondings to the characteristic impedance, as also is the line L3. A receiving end intermediate signal Z31 is obtained from the collector of the transistor T3 with a load resistance RC.

The connection of the inputs of the two other push-pull receivers GTE2 and GTE3 to the lines L1 to L3 is effected in a manner similar to that of the connection of the outputs of the corresponding transmitters. The receivers GTE2 and GTE3 supply further receiving-end intermediate signals Z32 and Z33.

A receiving-end coder network ECN3 serves to convert the intermediate signals Z31 to Z33 into the output signals A1 and A2 which are to be identical to the original input signals E1 and E2. In this example the receiving end coder network ECN3 also becomes extremely simple, as can easily be seen from Table 4, if the signals B31 to B33 and E1, E2 are replaced by the signals Z31 to Z33 and A1, A2 respectively. Here we have in fact A1=Z31 or A1=Z32 and A2=Z33. One of the two receivers GTE1 or GTE2 could thus be dispensed with.

The extremely simple method of deriving the transmitting end intermediate signals B31 to B33 from the input signals E1 and E2 on the one hand, and of deriving the output signals A1 and A2 from the receiving end intermediate signals Z31 to Z33 on the other hand does however involve the disadvantage that a change in only one input signal E1 or E2 can give rise to a change in the potentials on all three lines L1 to L3. This can give rise to the formation of so-called spikes at the receiving end. Table 5 illustrates one of several codes whereby, in the event of a change in only one input signal, potential changes occur only on two lines.

TABLE 5

E1	E2	B31	B32	B33	L1	L2	L3
		1	1	1	2	1	0
1	1	1	1	0	2	0	1
		1	0	0	1	2	0
1	0	0	1	1	1	0	2
0	1	0	0	1	0	2	1
0	0	0	0	0	0	1	2

The transmitting end and receiving end coder networks SCN3 and ECN3 must now be designed in accordance with the following logic equations:

$B31 = E1.E2$
$B32 = E1$
$B33 = E1 \not\equiv E2$
and:
$A1 = Z32$
$A2 = Z32 \not\equiv Z33$

In this case the push-pull receiver GTE1 is superfluous.

Here, as in the following exemplary embodiments, the coder networks have been fully characterised by the quoted logic functions. The logic function symbols which have been used represent
$+$ OR
$.$ AND
$\equiv$ logic identity
$\not\equiv$ exclusive or

As can be seen from Table 3, the computed value for the information which can be transmitted across a three-wire line group amounts to 2.585 bits. However in reality only two bits can be transmitted as can easily be seen and as also shown in the above described exemplary embodiment (although occasionally it may be possible to transmit three bits if not all input combinations are used). On the other hand it is possible to transmit 5 bits across two line groups each comprising three lines if an appropriate design of the transmitting end coder network ensures that at least some of the input signals E1 to E5 influence the potential distribution of both line groups.

Figure 3 illustrates the plan of a corresponding transmitting device. The receiving device is constructed in a similar fashion (see also Figure 2). In order that the transmitting end intermediate signals B321 to B326 may be derived from the input signals E1 to E5, the transmitting end coder network SCN32 is arranged to fulfil the following logic equations:

$B321 = E1$
$B322 = E1 \equiv (E3 + E4.\overline{E5})$,
$B323 = E1 \not\equiv (\overline{E3} + E5)$
$B324 = E2$
$B325 = E2 \equiv (E3 \equiv E4 + E4.\overline{E5})$
$B326 = E2 \not\equiv (E3 + E5)$

As regards the receiving end coder network ECN32 we then have

$A1 = Z321$
$A2 = Z324$
$A3 = (Z321 \equiv Z322) . (Z324 \not\equiv Z326)$
$A4 = (Z322 \not\equiv Z325) \equiv (Z321 \equiv Z324)$
$A5 = (Z321 \not\equiv Z323) . (Z324 \not\equiv Z326)$

As a further example Figure 4 illustrates a simplified transmitting device comprising 6 push-pull transmitters GTS1 to GTS6 for the transmission of 4 bits across a line group comprising four lines L1 to L4. The connection of the receiver inputs to the lines L1 to L4 corresponds to the connection of the transmitter outputs. As, of the 24 possible combinations of transmitting end intermediate signals, only 16 are required for the transmission of the four input signals, the possibility again exists of selecting the

means of deriving the transmitting end intermediate signals B41 to B46 from the input signals E1 to E4 to be as simple as possible and to ensure that in the event of a change in only one input signal the line potentials are changed on only two lines.

Table 6 illustrates an appropriate conversion of the input signals E1 to E4 into the transmitting end intermediate signals B41 to B46 and moreover into the line potentials on the lines L1 to L4. For this purpose it is necessary to use logic elements which fulfil the following logic functions in the transmitting end coder network SCN4:

$$B41 = (\overline{E1} + \overline{E2}) . (E2 + \overline{E3}).$$
$$B42 = \overline{E1}$$
$$B43 = (\overline{E1} + \overline{E2}) . (E2 + E3)$$
$$B44 = (\overline{E1} + \overline{E2}) . (E3 + E4)$$
$$B45 = E3$$
$$B46 = E1.E4 + E3.\overline{E4}$$

TABLE 6

E1	E2	E3	E4	B41	B42	B43	B44	B45	B46	L1	L2	L3	L4
0	0	0	0	1	1	0	0	0	0	2	0	1	3
0	0	0	1	1	1	0	1	0	0	2	1	0	3
0	0	1	0	0	1	1	1	1	1	2	3	1	0
0	0	1	1	0	1	1	1	1	0	2	3	0	1
0	1	0	0	1	1	1	0	0	0	3	0	1	2
0	1	0	1	1	1	1	1	0	0	3	1	0	2
0	1	1	0	1	1	1	1	1	1	3	2	1	0
0	1	1	1	1	1	1	1	1	0	3	2	0	1
1	0	0	0	1	0	0	0	0	0	1	0	2	3
1	0	0	1	1	0	0	0	0	1	1	0	3	2
1	0	1	0	0	0	1	1	1	1	1	3	2	0
1	0	1	1	0	0	1	0	1	1	1	2	3	0
1	1	0	0	0	0	0	0	0	0	0	1	2	3
1	1	0	1	0	0	0	0	0	1	0	1	3	2
1	1	1	0	0	0	0	1	1	1	0	3	2	1
1	1	1	1	0	0	0	0	1	1	0	2	3	1

Table 6 will apply to the receiving end if the transmitting and intermediate signals Z41 to Z46 and the input signals E1 to E4 are replaced by the output signals A1 to A4. For the conversion, the receiving end coder network must execute the following logic functions:

$$A1 = \overline{Z42}$$
$$A2 = Z41 \equiv Z43$$
$$A3 = Z45$$
$$A4 = Z44 \not\equiv Z46.$$

As the measures in accordance with the invention ensure that the sum of the potentials within a line group and thus also the mean group potential remain constant, by combining two or more line groups it is possible to form phantom circuits. Thus for example in the exemplary embodiment illustrated in Figure 3 it is possible to form a 2-line phantom circuit and thus to increase the overall transmission capacity from 5 bits to 6 bits.

In the case of more than two groups, the same measures which have been described above in respect of groups composed of more than two lines can be used for the phantom circuits. Usually each group will have the same number of lines. Table 7 illustrates a few characteristic values in dependence upon the total number *n* of the lines and the number *m* of the line groups employing phantom circuits. It is assumed that each group has *n*/*m* lines and that only one phantom group is formed by the main

groups, although this is not essential. It may be noted that the bit capacity for m groups each with x lines is the sum of the bit capacity $\Sigma(\log_2(x!))$ of the individual groups, plus that of the phantom circuits, the actual bit capacity being, of course, the largest integer less than this total. Where the number of lines per group is constant, $x = n/m$.

TABLE 7

No. of Lines	No. of Groups	Lines per Group	Potentials	No. of Combinations	Information (bits)	Information/ per line (bits)
4	1	4	4	24	4.585	1.146
4	2	2	3	8	3	0.750
6	1	6	6	720	9.492	1.585
6	2	3	4	72	6.170	1.028
6	3	2	4	48	5.585	0.931
8	1	8	8	40320	15.299	1.912
8	2	4	5	1152	10.170	1.271
8	4	2	5	384	8.580	1.073
9	1	9	9	362880	18.469	2.052
9	3	3	5	1296	10.339	1.148
n	m	n/m	m+n/m−1	z	$\log_2 z$	$(\log_2 z)/n$

$z = [(n/m)!]^m \cdot m!$

From the varioius possibilities of forming grouped line systems based on the values n and m, the line arrangement comprising three line groups each containing three lines may be singled out as it permits an electrically advantageous cabling technique in which the mutual couplings between the lines belonging to various groups balance one another even at relatively short line lengths (≈0.1 m). This produces a phantom characteristic impedance which is only slightly smaller in value than the characteristic impedance of the individual lines.

The overall transmission capacity of an arrangement of this kind amounts to 10 bits, since 4 × 2.585 bits = 10.34 bits where 2.585 bits as shown in table 3 is the theoretical value of the transmission capacity of a three-line group. This also results in a comparatively low number of line potentials as can also be seen from the aforementioned Table 7. The number of the line potentials is in fact $n + n/m - 1$, and for $m = \sqrt{n}$ becomes a minimum, where n and m have been assumed to be whole numbers.

In this case however the formation of the intermediate signals for the transmitter group of the phantom circuits is assisted by input signals which in fact control the derivation of the intermediate signals for the transmitter groups of the individual line groups. The reverse conditions apply at the receiving end. As, however, the transit times on the physical line circuits and on the phantom circuits differ somewhat from one another on account of the different characteristic impedances, false output signals can occur at the receiving end for the duration of the transit time differences.

Although not particularly serious, this shortcoming can be avoided if the transmitting and receiving devices are designed to transmit 9 bits, thus abandoning the maximum transmission capacity but enabling the phantom circuits to operate independently of the main coding circuits. A bit group of this kind represents, as is known, an information unit which is frequently used in data technology in which 8 bits are normally interpreted as data bits and the ninth bit as a parity bit.

Figure 5 schematically illustrates a corresponding transmitting device comprising transmitter groups SG1 to SG3 and SGP which operate on the line groups L11 to L13, L21 to L23, and L31 to L33, and on the phantom circuits. The transmitting end intermediate signals B331 to B339 are derived from the input signals E1 to E7, and the intermediate signals B33A to B33C are derived from the input signals E8 and E9 by means of separate coder networks SCN33 and SCP. The lines are terminated by resistors R which are matched to the characteristic impedance of the individual lines, and the additional

resistors R′ form the matching to the characteristic impedance of the three-line group. As regards the receiver groups, which are directly connected to the lines, as in the case of the previously discussed exemplary embodiments the receiving device is of similar design to the transmitting device and therefore need not be described in detail. One exception, which remains to be discussed, consists of the receiver group which is assigned to the phantom circuits.

The conversion of the input signals into the transmitting-end intermediate signals by means of the coder networks SCN33 and SCNP can be effected by means of the following logic equations:

$$
\begin{aligned}
&B331 = E1\\
&B332 = E1 \equiv E7\\
&B333 = \overline{E1}\\
&B334 = E2\\
&B335 = E2 \equiv (\overline{E6} + E4.E5)\\
&B336 = E2 \not\equiv (\overline{E5} + \overline{E4}.E6)\\
&B337 = E3\\
&B338 = E3 \equiv (E4 + E5.E6) \quad B339 = E3 \not\equiv (E4 + E5.E6)\\
&B33A = E8.E9\\
&B33B = E8\\
&B33C = E8 \not\equiv E9
\end{aligned}
$$

The following recoding procedure must then be carried out at the receiving end:

$$
\begin{aligned}
&A1 = Z331\\
&A2 = Z334\\
&A3 = Z337\\
&A4 = (Z338 \not\equiv Z337) + Z339 \not\equiv Z337) . (Z336 \not\equiv Z334)\\
&A5 = (\overline{Z336} \not\equiv Z334) + \overline{(Z338} \not\equiv Z337) . (Z339 \not\equiv Z337)\\
&A6 = (Z335 \not\equiv Z334) + (\overline{Z336} \not\equiv Z334) . (Z338 \not\equiv Z337)\\
&A7 = \overline{Z332} \not\equiv S331\\
&A8 = Z33B\\
&A9 = Z33B \not\equiv Z33C
\end{aligned}
$$

It will be clear from the above list that only two receiving end intermediate signals, namely Z33B and Z33C are required for the derivation of the output signals A8 and A9. As a result one push-pull receiver can be dispensed with in the receiver group assigned to the phantom circuits.

As in the case of the double line, in the line systems here under consideration it is possible to carry out a simultaneous bidirectional operation (duplex operation). A transmitting-receiving device suitable for this purpose which is to be connected to one pair of lines in all the combinations possible in the case of more than two lines (without repetition), is known for example from German Patent 26 33 066. However in duplex operation it should be noted that the number of line potentials is $2.(m + n/m - 1) - 1$, i.e. is virtually doubled in comparision to unidirectional transmission.

CLAIMS

1. A data transmission system comprising n lines, where n is greater than or equal to three, connected to at least n push-pull transmitters, each transmitter being connected to a different pair of the lines, coder means responsive to binary input signals supplied thereto to control the transmitters so as to produce signal states on the lines corresponding to respective combinations of the input signals, and receiving means comprising a plurality of receivers each responsive to the states of a different pair of the lines and coder means arranged to produce binary output signal combinations corresponding to respecitve input signal combinations.

2. A data transmission system according to claim 1, having $\frac{1}{2}n(n-1)$ said transmitters.

3. A data transmission system according to claim 2, in which the transmitter coder means has k binary inputs where k is the largest integer less than $\log_2(n!)$, whereby all combinations of the binary input signals can be transmitted.

4. A data transmission system according to claim 1, in which the said n lines comprise at least two groups of at least three lines, each group being assigned a separate group of $\frac{1}{2}x(x-1)$ transmitters, where x is the number of lines in the relevant group.

5. A data transmission system according to claim 4, in which each group has the same number of lines.

6. A data transmission system according to claim 4 or 5 in which the coder means [illegible] each group, an independent coder section having k' binary inputs where k' is the largest integ[illegible] $\log_2(x!)$.

7. A data transmission system according to claim 4 or 5 in which the transmitter c[illegible]s has, in respect of at least some of the groups, interdependent coder sections having together [illegible] inputs where k'' is the largest integer less than the sum of the $\log_2(x!)$ for the relevant gro[illegible]

8. A data transmission system according to any one of claims 4 to 7 in which one or more phantom circuits are formed by the groups.

9. A data transmission system according to claim 8 with at least three groups, the phantom circuits being arranged in accordance with any one of the preceding claims.

10. A data transmission system according to claim 9 in which the transmitter coder means for the phantom circuits is arranged to operate independently of the transmitter coder receiver for the lines.

11. A data transmission system according to claim 9 in which the transmitter coder means for the phantom circuits and the transmitter coder means for the lines are interdependent, sharing at least some of their signal inputs.

12. A data transmission system substantially as hereinbefore described with reference to figures 1 and 2 of the accompanying drawings.

13. A data transmission system substantially as hereinbefore described with reference to figure 3 of the accompanying drawings.

14. A data transmission system substantially as hereinbefore described with reference to figure 4 of the accompanying drawings.

15. A data transmission system substantially as hereinbefore described with reference to figure 5 of the accompanying drawings.

16. Device for push-pull transmission of an item of binary information across line groups comprising $n \geqslant 3$ lines, with push-pull transmitters and push-pull receivers, characterised by a transmitting-end coder network (SCN) which serves to form $s = (n-1)\,n/2$ control signals (B1 to Bs) for the control of s push-pull transmitters (GTS1 to GTSs) whose outputs are connected in s combinations without repetition to the n lines (L1 to Ln), from k input signals (E1 to Ek) which are to be transmitted, where k is the largest integer less than $\log_2(n!) < 1d\,(n!)$, by s push-pull receivers (GTE1 to GTEs) whose inputs are connected to the lines (L1—Ln), and by a receiving-end coder network (ECN) which serves to form output signals (A1 to Ak), which are identical to the input signals (E1 to Ek) from the intermediate signals (Z1 to Zs) emitted from the push-pull receivers (GTE1 to GTEs).

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1981. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.